



New Development Activities at NASA Ames in Reusable TPS Materials

Adam Caldwell*, Jay Feldman#, Peter Marshall*

*Analytical Mechanics Associates at NASA ARC

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Overview

- Reusable Thermal Protection Materials Background
- Development efforts
 - AETB Modernization
 - Flexibles
 - Next Generation Tile
 - Leading Edge System
- Commercial Collaboration
- Added capability

Reusables Background - Shuttle



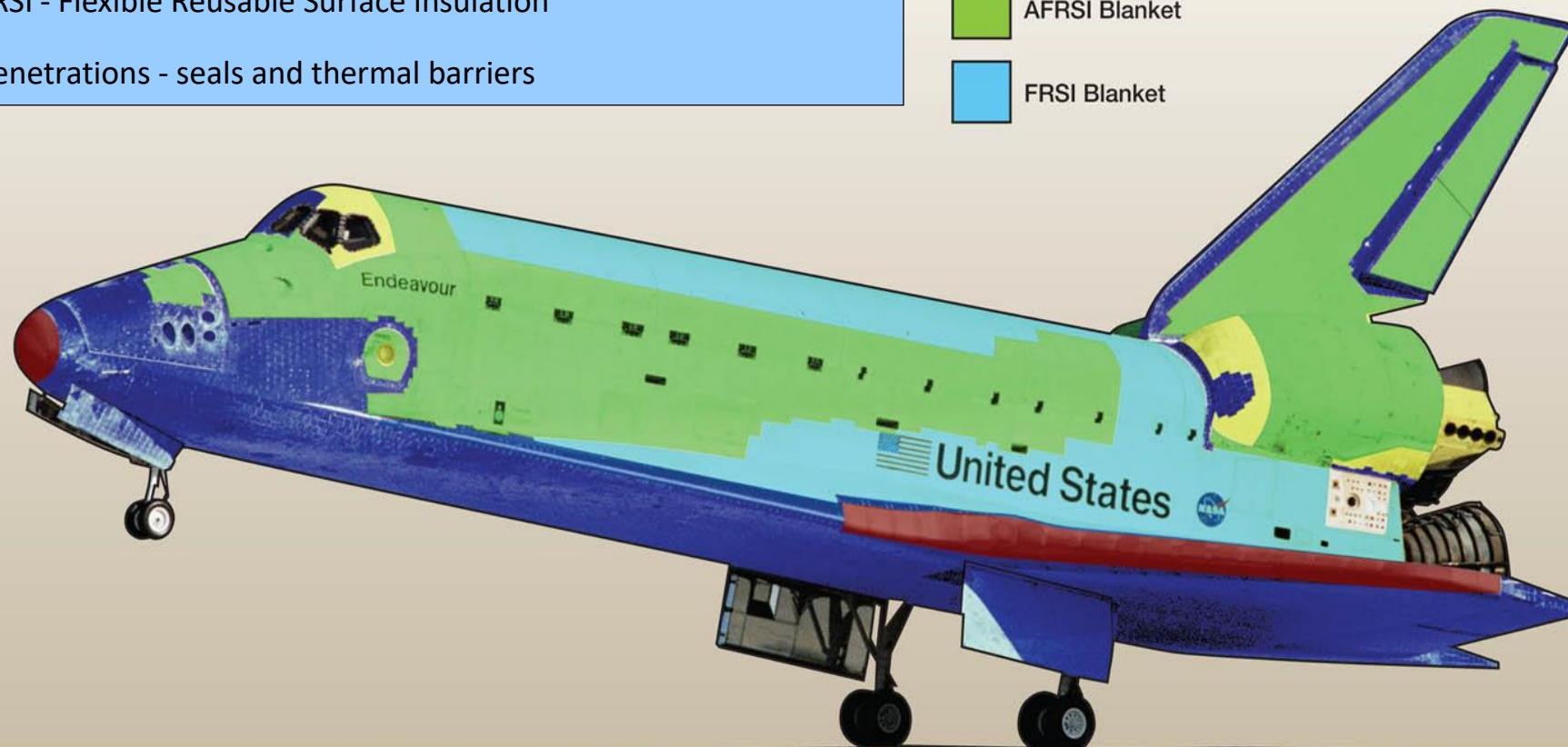
- Reusable thermal protection systems were developed for the Space Shuttle (1960's-70's)
- Engineered to survive 100 use cycles
- Variety of materials were used throughout the system
 - Flexibles such as FRSI and AFRSI
 - Ceramic tiled systems like HRSI and LRSI
 - Leading edge material – reinforced carbon/carbon (RCC)



Space Shuttle Discovery approaches for landing on a concrete runway at Edwards Air Force Base

Shuttle Orbiter TSP Configuration

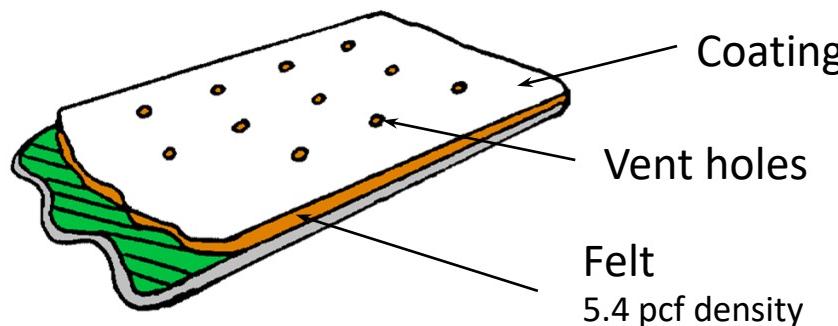
- RCC - Reinforced Carbon-Carbon
- HRSI - High-temperature Reusable Surface Insulation
- LRSI - Low-temperature Reusable Surface Insulation
- AFRSI (FIB) - Advanced Flexible Reusable Surface Insulation
- FRSI - Flexible Reusable Surface Insulation
- Penetrations - seals and thermal barriers



Flexible Materials

Flexible Reusable Surface Insulation (FRSI)

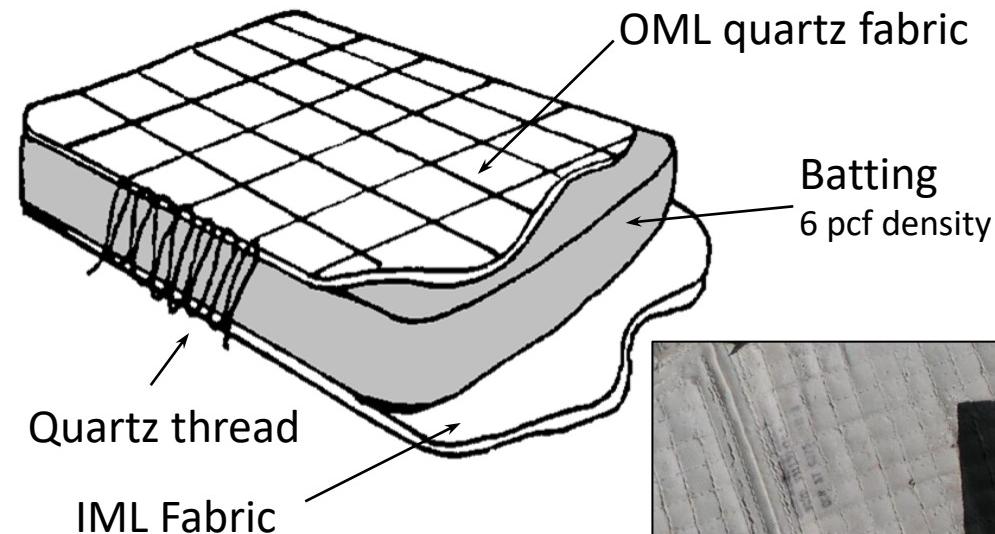
- Needled Nomex felt
- Silicone coating
- Can be made multi-layer



Multi-use Temperature < 700 °F

Advanced Flexible Reusable Surface Insulation (AFRSI)

- Glass fabric outer cover
- Q-felt batting
- Stitched with glass thread

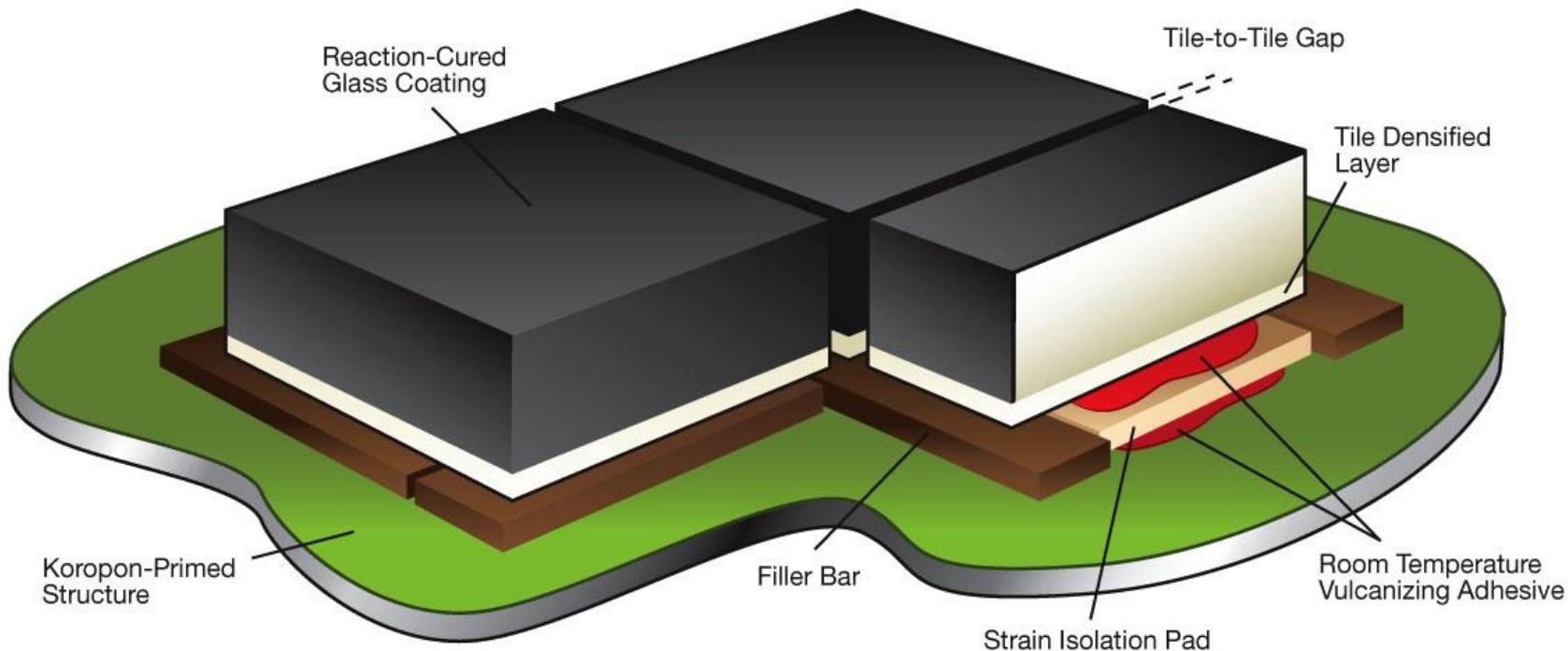


Multi-use Temperature < 1500 °F



HRSI Tile System

- High temperature reusable surface insulation (HRSI) tiles are made from ceramic fibers and have very low densities
- Utilize a black coating, called reaction cured class (RCG), for high emittance on entry



Materials:

- LI-900
- LI-2200
- FRCI-12
- AETB-8
- BRI-18

essentially
obsolete

current
materials

Multi-use
temperature range[#]:

~2300 - 2700 °F

#dependent on material
& exposure duration

Space Shuttle Orbiter

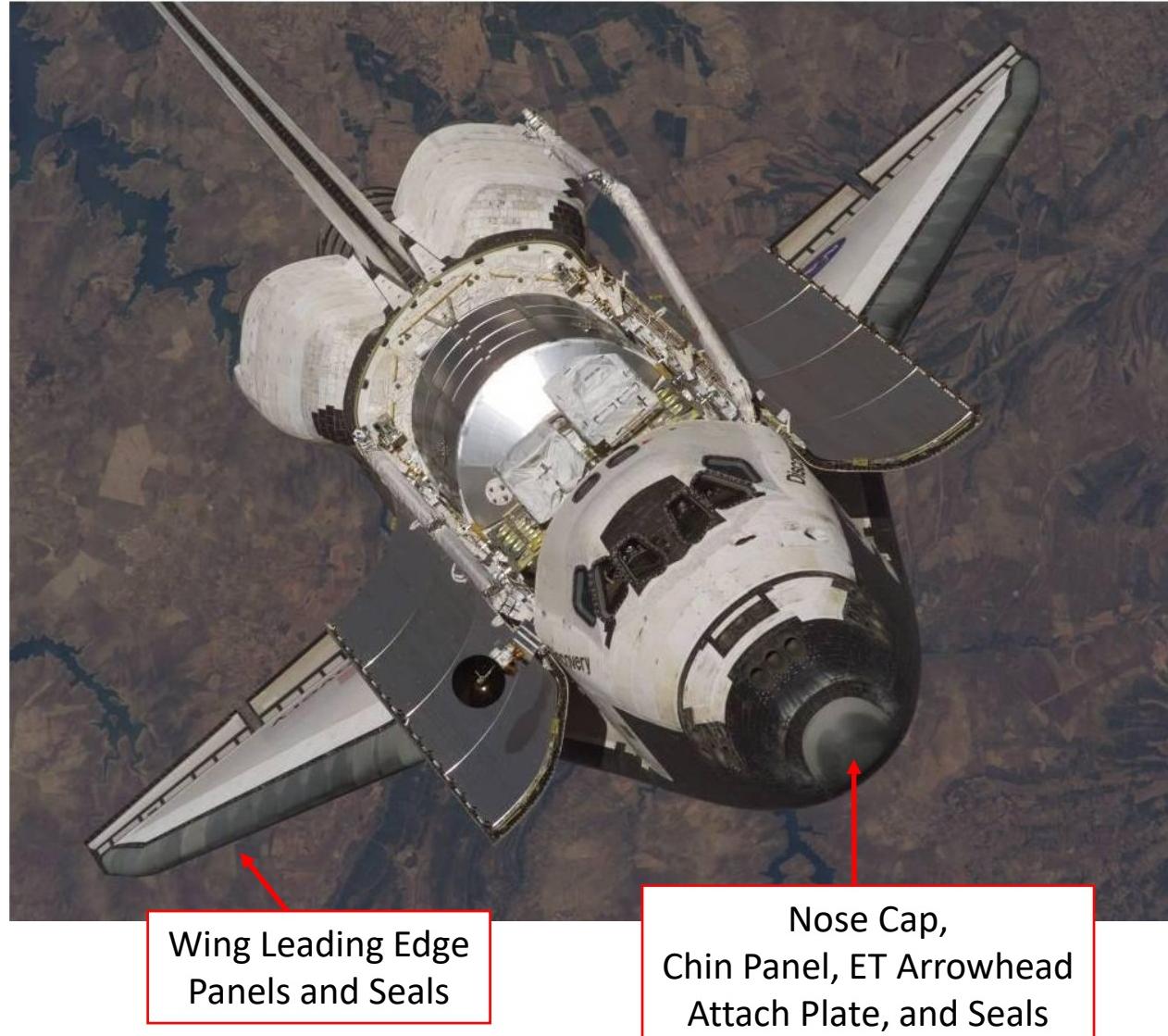


Space shuttle Discovery as viewed from the ISS for inspection of the heat shield

Reinforced Carbon/Carbon (RCC)



- Thermal Protection
 - Multi/Single 3000 °F / 3,220 °F
 - **Hot structure** requiring internal insulation
- Aerodynamic Shape
 - Maintain airfoil shape for flight
- Load Distribution
 - Aerodynamic **load transmission**

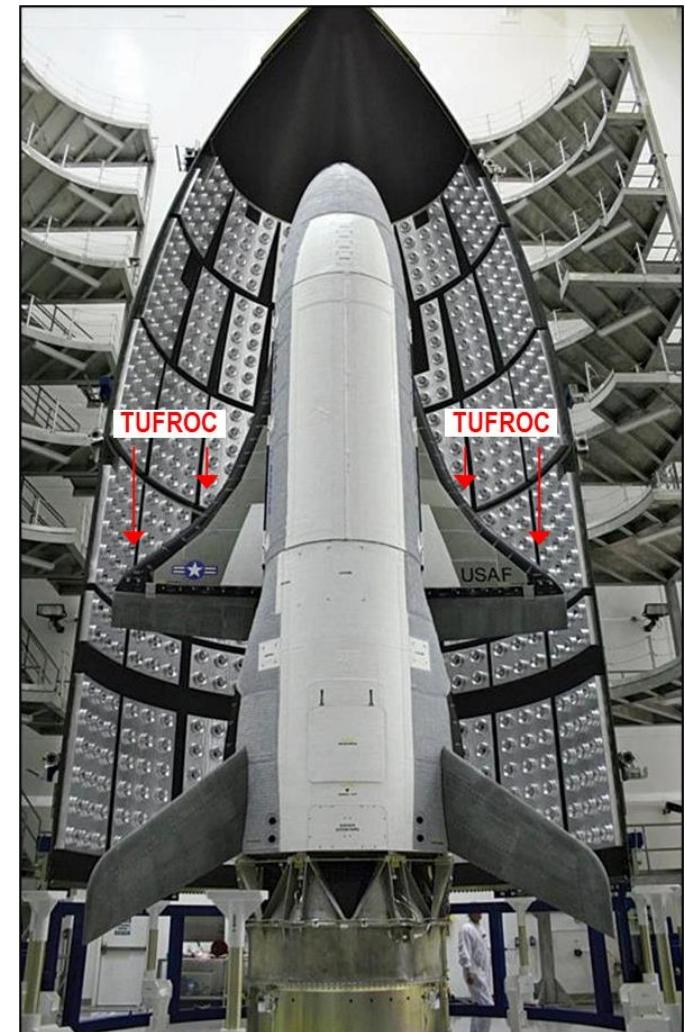


Advanced TUFROC



- “Toughened Uni-piece Fibrous Reinforced Oxidation-Resistant Composite”
- A multi-component tiled TPS system that is the state-of-the-art reusable material system used on the leading edges of X-37B
- Features (vs. C/C or C/SiC)
 - Low cost (10x cheaper than C/C)
 - Light weight ($\sim 0.3 \text{ g/cm}^3$)
 - Insulative
 - Reusable temperature 2900°F ($\geq 3, 5\text{min}$ exposures)
 - Single-use temperature exceeding 3100°F

X-37B preparing for 1st launch, 2010

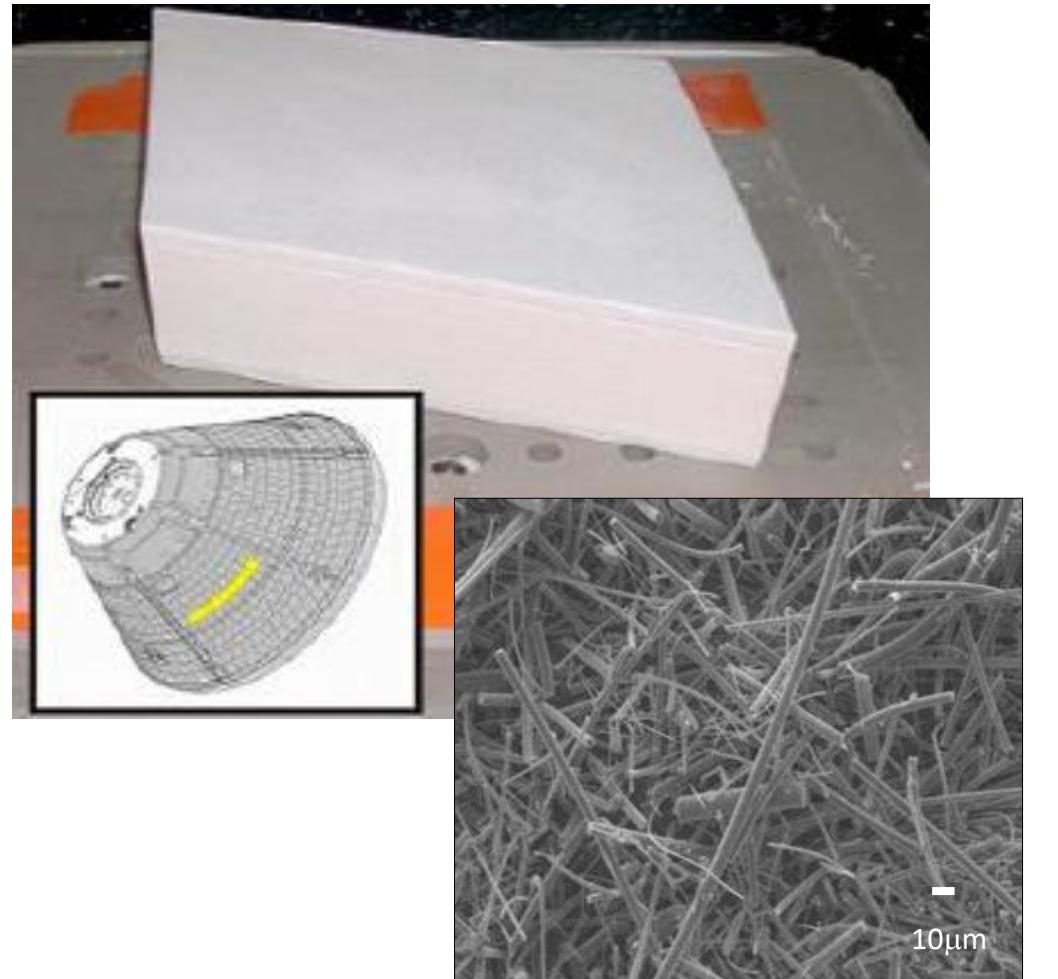


Alumina Enhanced Thermal Barrier (AETB)



- State-of-the-art reusable thermal protection material although it was developed in the 1990's
- AETB-8, -12, -17, -20 (pcf)
 - Densities of 0.13 to 0.32 g/cm³
- Main constituents:
 - High purity silica fiber (Q-fiber)
 - Alumina fiber (Saffil)
 - Aluminoborosilicate fiber (Nextel-312)
- Best dimensional stability of the tile materials
- Max use temperature ~2800 °F (single use)

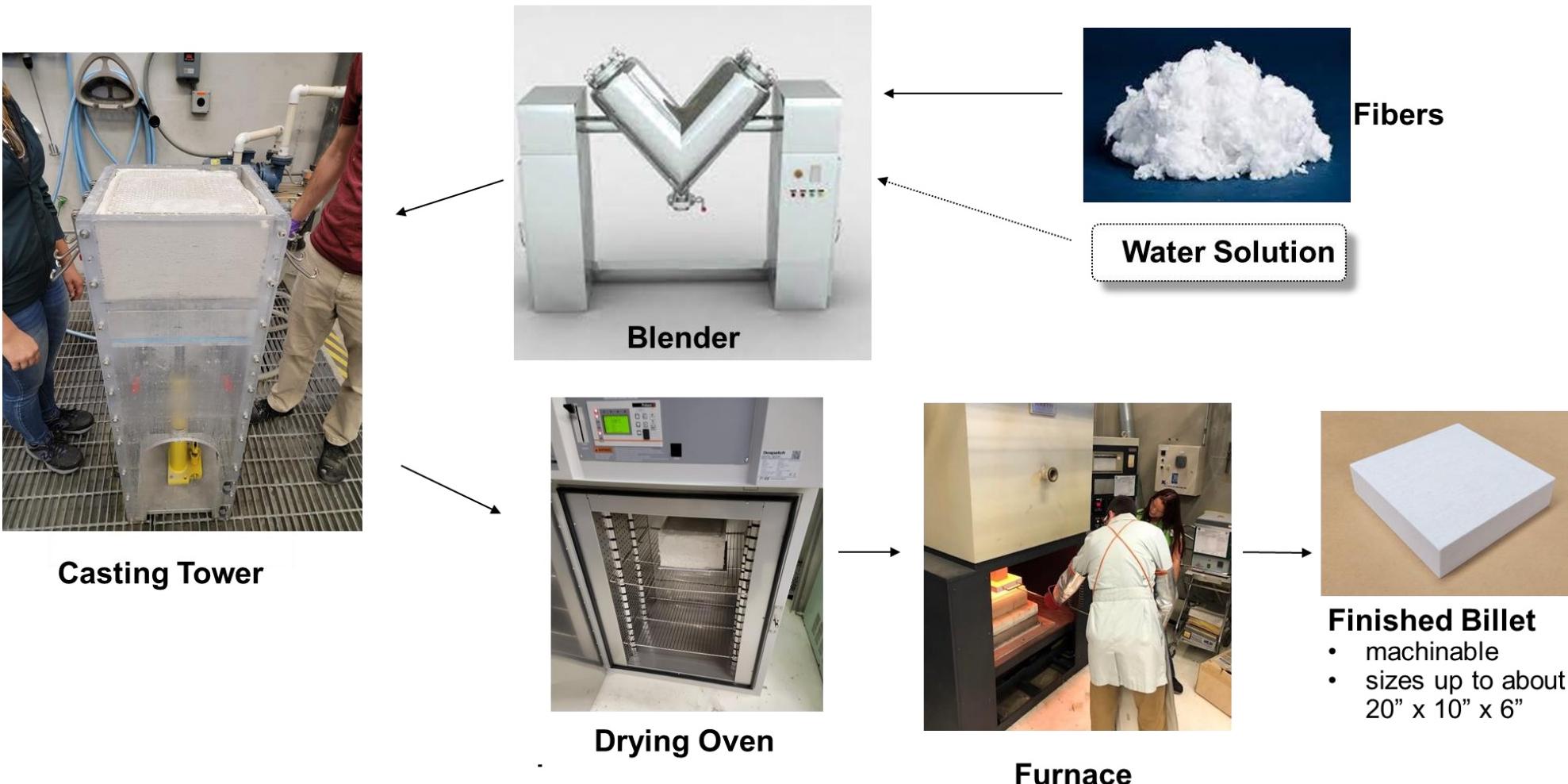
AETB-8 fabricated for Orion backshell



SEM Image of
AETB-8

Tile Production Process

Tile Process Schematic





AETB Modernization

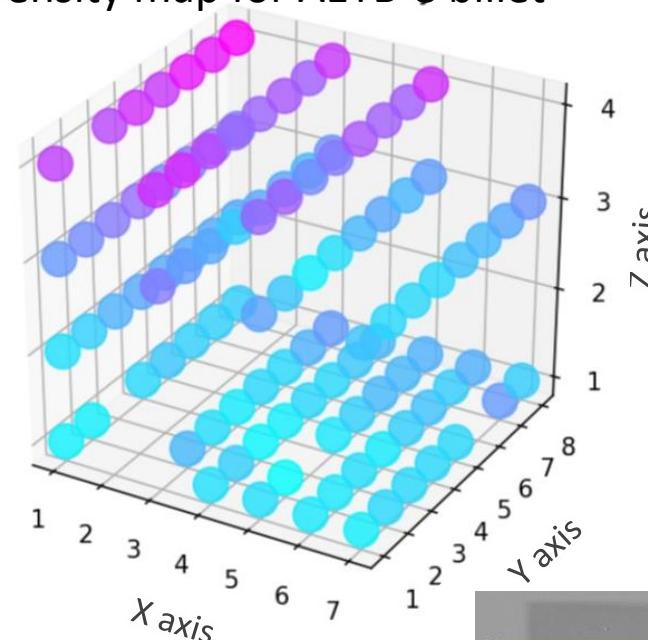
Motivation

- AETB has historically been made using raw materials from lifetime buys that were made during the Shuttle era.
- This **stockpile** will be **consumed** via planned Orion missions
- Modern materials **process differently** and have produced tiles that do not meet AETB-8 spec using historical processing procedures
- Commercial space industry are stuck using modern materials

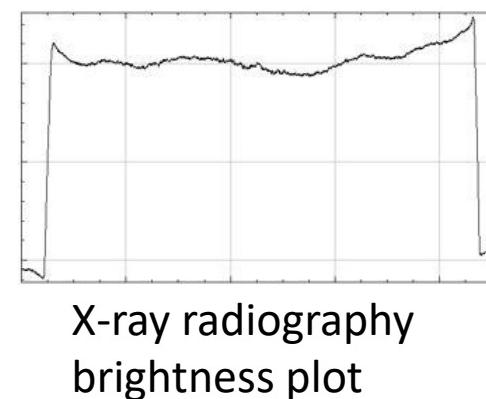
AETB Modernization

- Developing the process for producing AETB-8 using modern materials that meet historical specs
- Gaining a better understanding of the process to inform scale up and future modifications
 - Fiber mixing/Tile casting
 - Different fiber mixing modalities
 - Raw material factors
 - Firing
 - Instrumentation using in-depth thermocouples to measure thermal profiles
 - Material characterization
 - Density measurement methods
 - Mechanical properties - Tensile Test
 - Thermal Conductivity

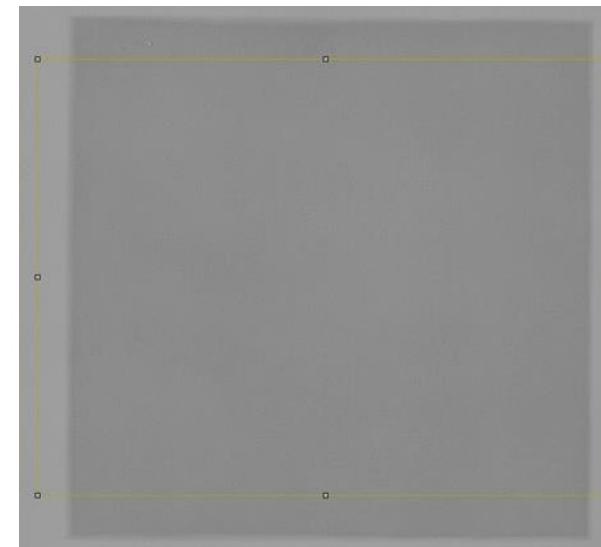
Density map for AETB-8 billet



X-ray radiography of AETB-8 billet



X-ray radiography brightness plot



Next Generation Flexible and Tile Materials



Flexibles

- Small projects utilizing felt materials targeting lower max temperature applications
- Surveyed and procured commercially available felt and ridgizing products

Tiles

- Continuation of the process characterization efforts within AETB modernization
- Investigating the use of lower cost widely produced alternate ceramic fibers
- Implementing alternate processing modalities to allow for different microstructures and tile integration methods

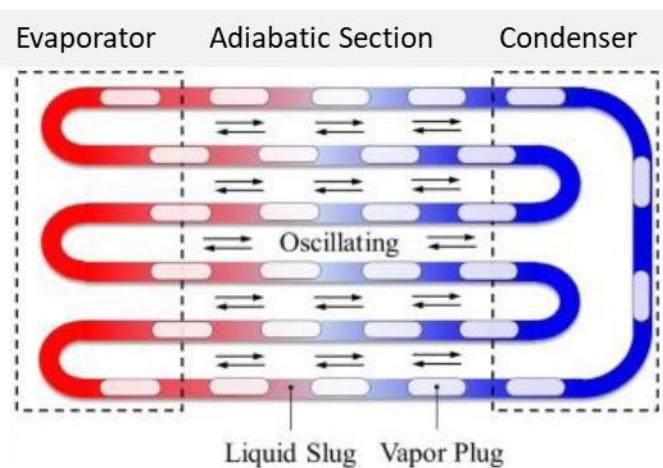
Preliminary torch testing of felt materials



Leading Edge Systems

Oscillating Heat Pipes (OHP)

- Developing additively manufactured structures for OHP applications
- Heat transfer driven by thermal excitation of liquid/vapor slugs/plugs that cause oscillation
- Capable of transporting extremely high heat fluxes
- POC: **Keith Peterson**



Oscillating Heat Pipe Schematic

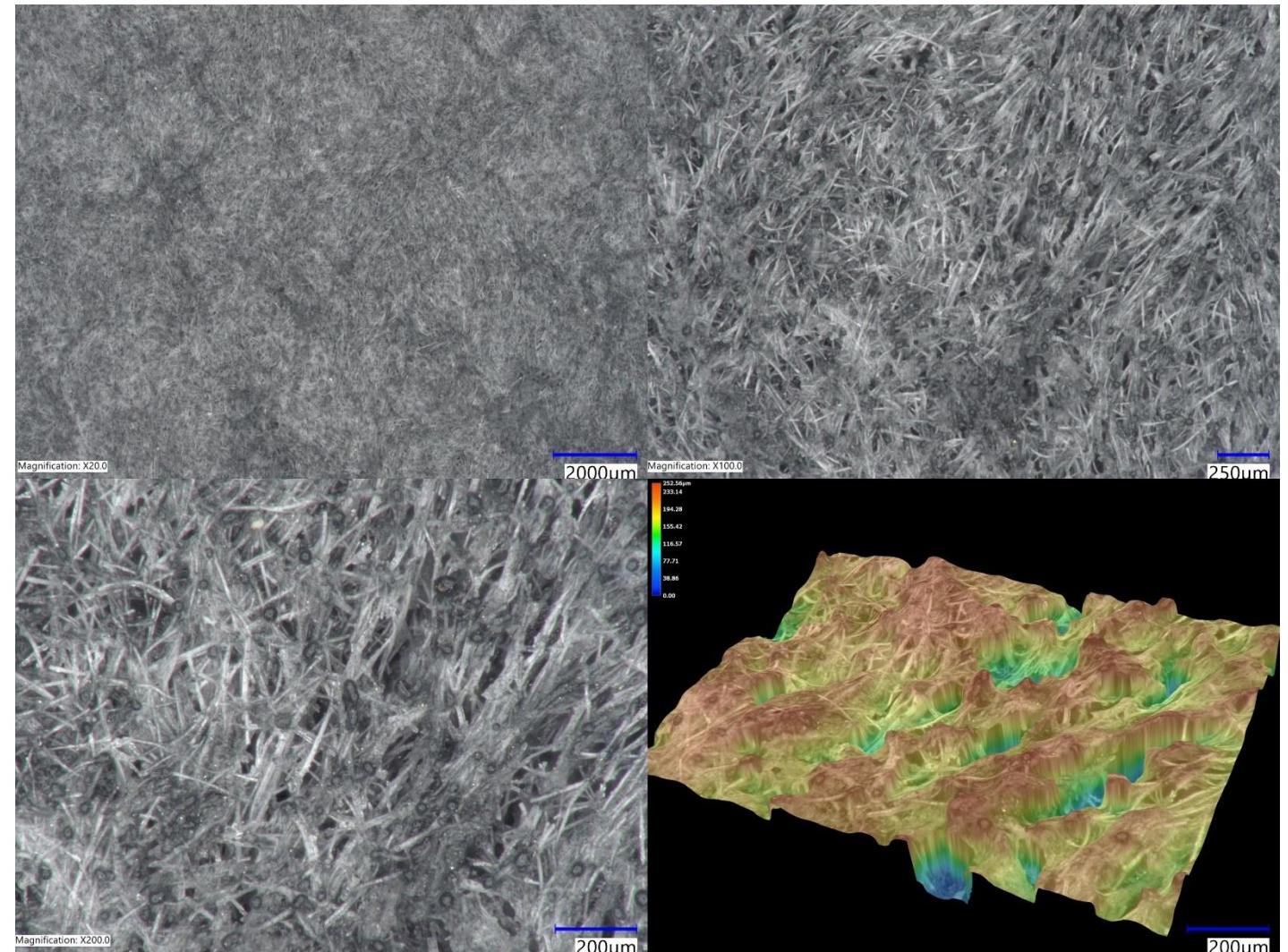
Next-generation TUFROC

- Investigating factors limiting maximum temperature of Advanced TUFROC utilizing historically available arc jet test coupons (work shown at CMS23)
- Potential for further increasing time at temperature and max temperature limits
- Developing drop-in alternative materials to simplify production pathways and reduce production complexity

Added Capability

- Added characterization within TSM branch
 - Keyence digital microscope with laser-induced ablation spectroscopy (LIBS)
 - Rigaku Miniflex 6G X-ray diffractometer
 - Upgraded SEM with new EDS detector and software

Optical photos (20x – 200x) with a 3D reconstruction height map



Commercial Collaboration



- NASA supporting through Announcement of Collaboration Opportunity (ACO) Projects on development of reusables
 - Blue Origin
 - Canopy Aerospace
 - Lockheed Martin
 - Stratolaunch
- Reimbursable Space Act Agreements (RSAA) focusing on reusables
 - Blue Origin
 - Canopy Aerospace
 - Stratolaunch

Open to more!



BLUE ORIGIN



STRATOLAUNCH

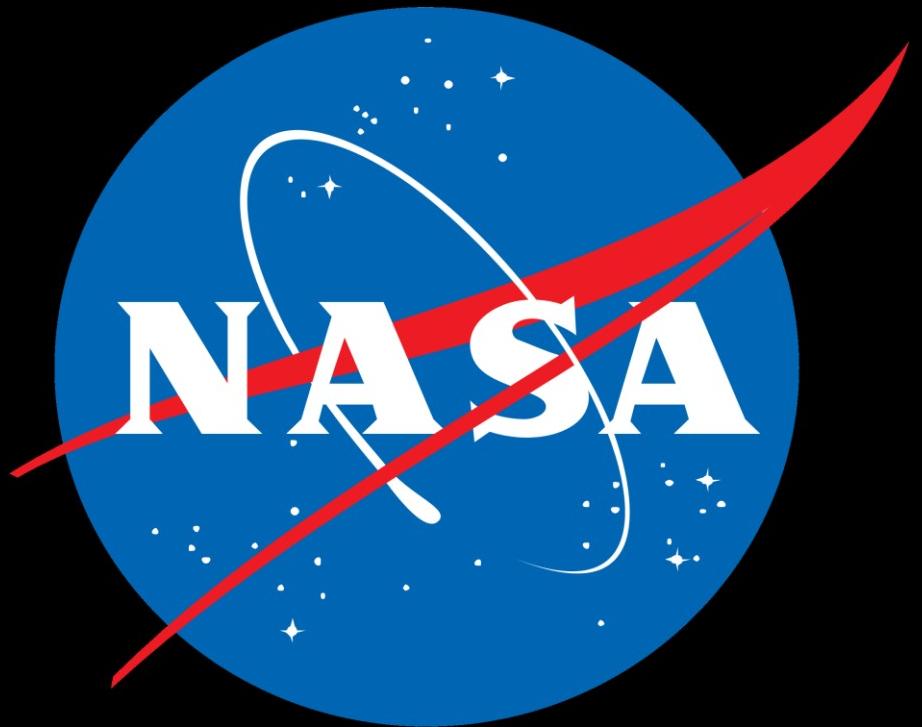




Thank you for your time!

Questions?

National Aeronautics and Space
Administration



Ames Research Center
Entry Systems and Technology Division